251 Presentations
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Use of Cure Modeling in Process Planning to Improve SLA Surface Finish

Benay Sager

SRL Presentation

June 7, 2005

Objectives of Research

- Investigate and develop an analytical model of the cured shape based on dynamic laser beam characteristics
- Validate model by comparing surface finish to SLA parts
- Formulate SLA parameter estimation problems that will systematically explore SLA parameter design space
- Solve parameter estimation problems for example parts
  - Improve surface finish → **Figure of Merit: Minimum Feature Size / Surface Roughness**

Current: / Improved:

300 μm / 10-20 μm / 0.1-2 μm

Overall Goal:
Improve SLA surface finish for rapid manufacturing

Step 1:
Analysis of SLA resolution by developing analytical cure model

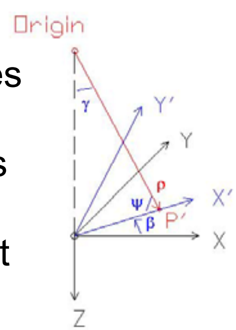
→

Step 2:
Application of analytical cure model in process planning to improve SLA surface finish

Analytical Cure Model Development

- Mathematical model is based upon known physical relationships involving resin, lasers, and optics

1. Given:
- Resin properties
- Machine and laser properties
- Laser location
  Point of interest



$$H(P) = \frac{H_O \exp\left(\frac{-\left(\frac{2\left\|D_{wp}\right\|^2}{d_o^2}\right)}{1+\left(\frac{Z_{wp}}{z_R^2}\right)^2}\right)\exp\left(-\frac{g}{D_p}\right)}{1+\left(\frac{Z_{wp}}{z_R^2}\right)^2}$$

2. Calculate Irradiance at a point P in the vat

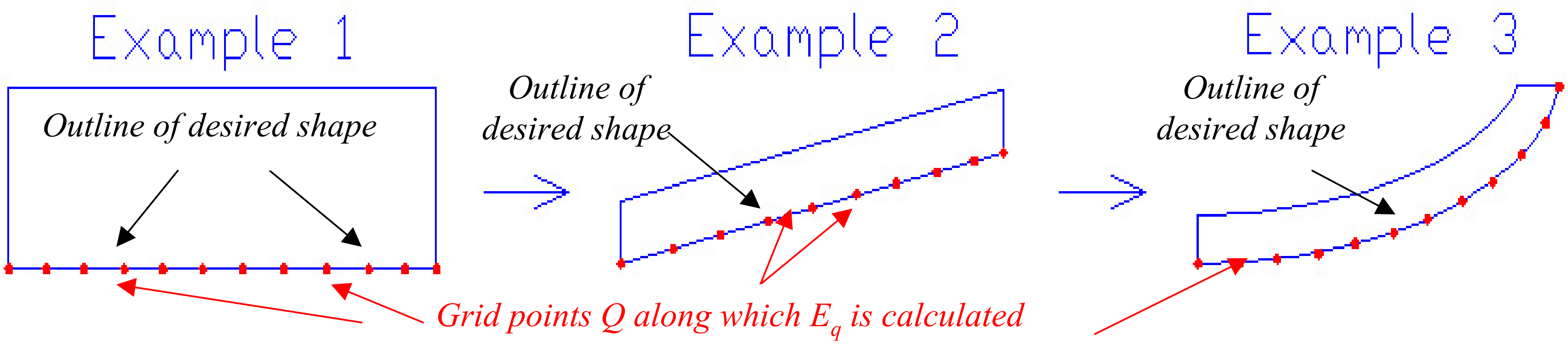
3. Calculate Exposure at point P over a period of time

$$E(x,y,z) = \int_{t=-\infty}^{t=\infty} H[x(t), y(t), z(t)]\,dt$$

4. Compare with critical value of exposure to see if resin has solidified at a particular point (threshold model)

SLA Parameter Estimation Problem for Process Planning

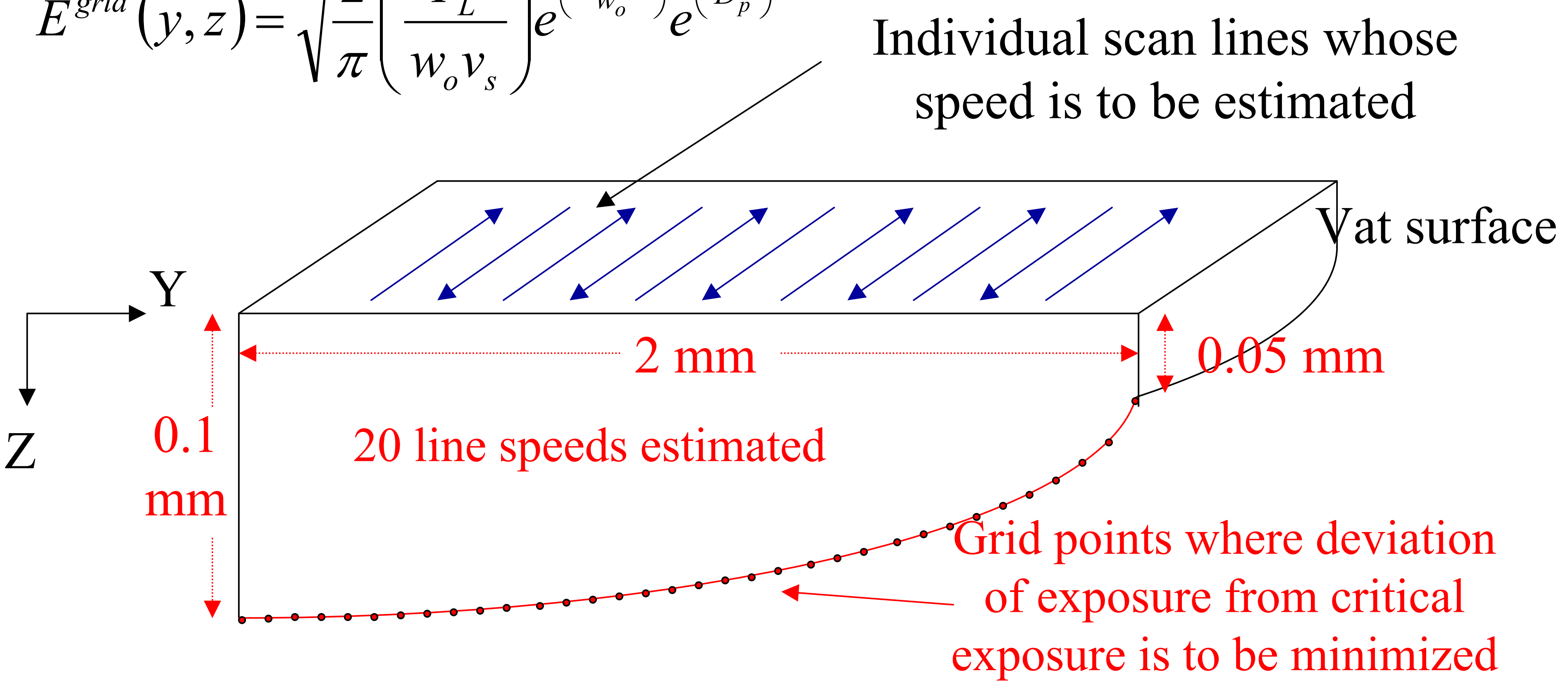
- Minimize deviation from Ec on surface using least squares minimization



- Estimate values of parameters that will improve surface finish
- Parameters will include **scan speed**, **hatch spacing**, **laser beam diameter**, **laser beam angle** and others

Sample Inverse Design Formulation

$$E^{grid}(y,z)=\sqrt{\frac{2}{\pi}}\left(\frac{P_L}{w_o v_s}\right)e^{\left(\frac{-2y^2}{w_o^2}\right)}e^{\left(\frac{-z}{D_p}\right)}$$



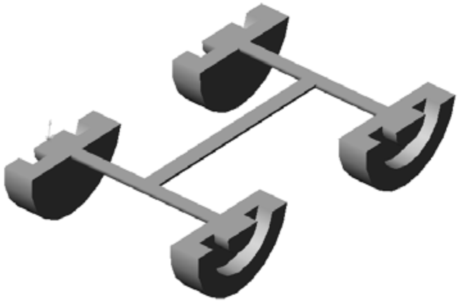
Process Planning Method for Mask Projection Stereolithography

Ameya Limaye

SRL Presentation

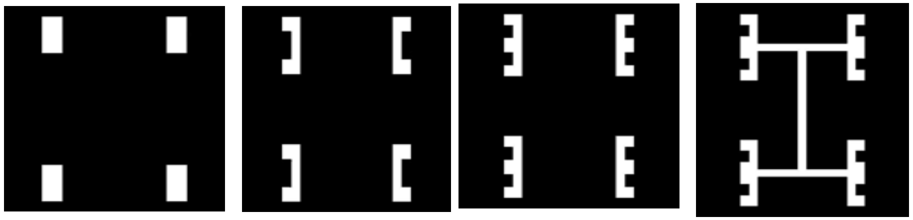
June 7, 2005

Mask Projection Stereolithography



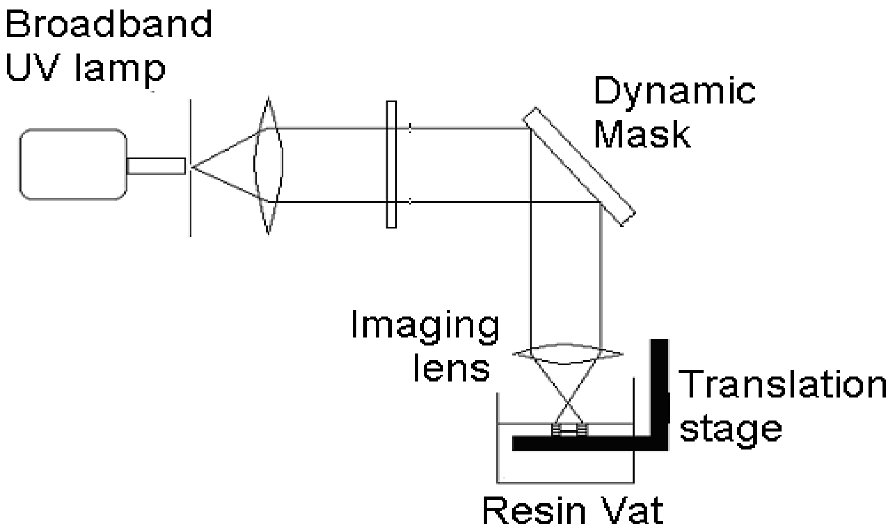
CAD model

Sliced by computer



Bitmaps corresponding to every layer

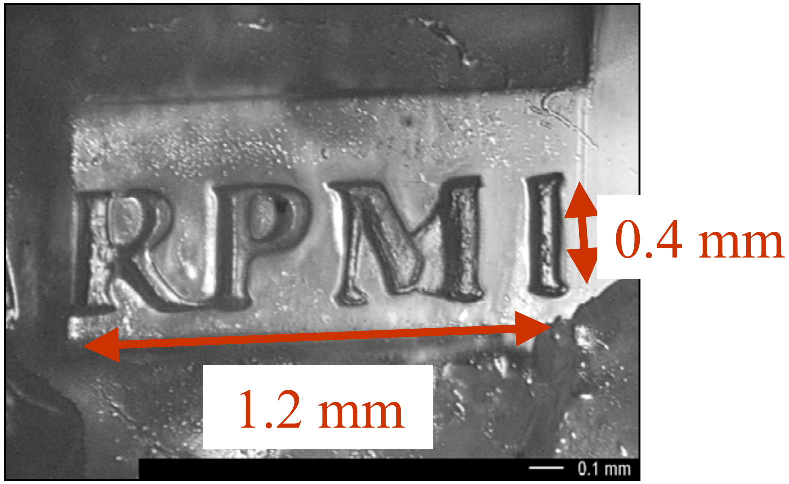
Bitmaps displayed on mask



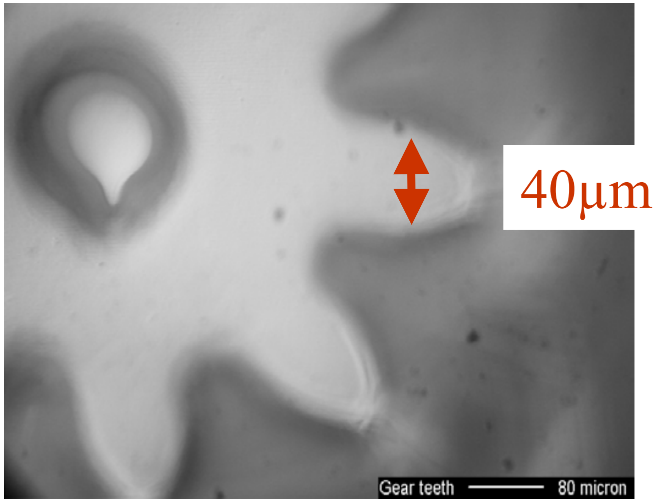
Layers cured upon each other

Cured polymer part

Work Already Done



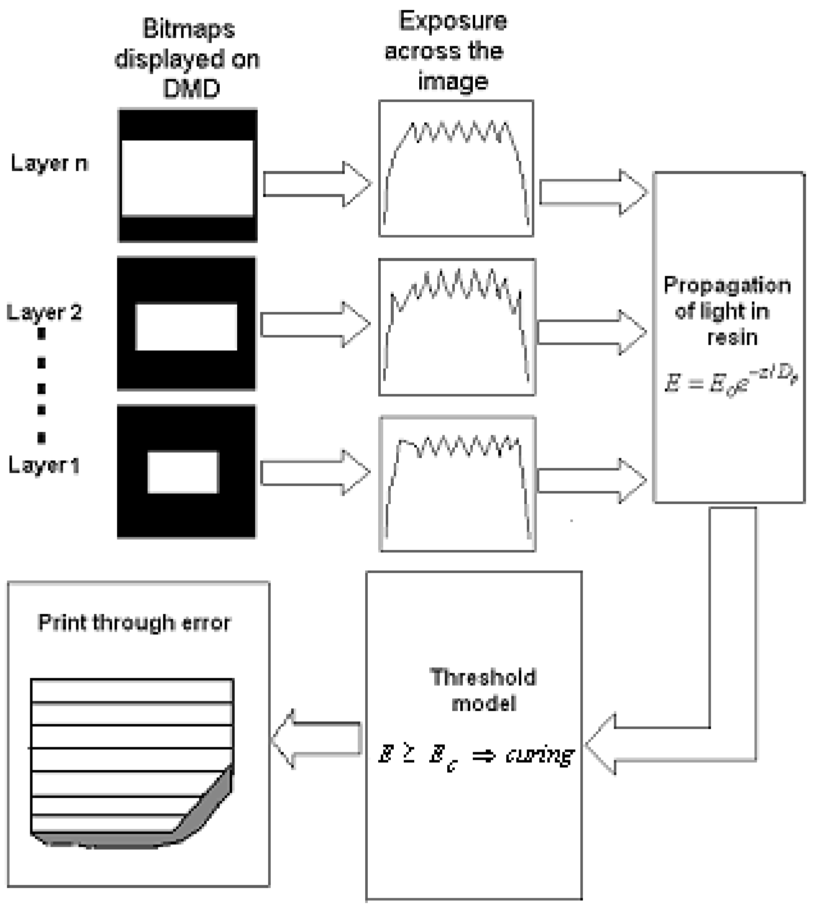
RPMI logo



Micro Spur gear

- Process of curing of a single layer modeled analytically as Layer Cure model
- Layer cure model validated on the system
- Process planning method to cure single layered parts with accurate lateral dimensions formulated and tested

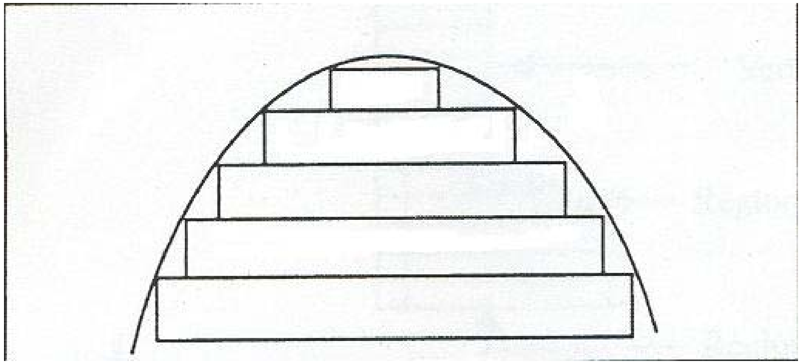
Errors in Z Direction



Print through error

- Radiation penetrates beyond the intended layer thickness
- Resin at the bottom of the part receives radiation penetrating from all layers cured above it
- Unwanted curing occurs at the bottom of the part to create errors in Z direction

Stair Stepping



Approximating curved surface by stair-steps (Jacobs, 1997)

- Mask Projection SLA part built layer by layer
- Slanting and curved surfaces approximated by stair-steps
- Stair stepping leads to errors in lateral direction and poor surface finish

Robustness Against Changes in Resin Properties

- Curing characteristics of Stereolithography resins change with time
- Resin properties likely to change in the course of the build due to dumping of radiant energy into the bulk resin in the vat
- Resin properties can change from batch to batch of resin
- Process parameters should be so chosen that the process becomes robust against changes in the resin properties

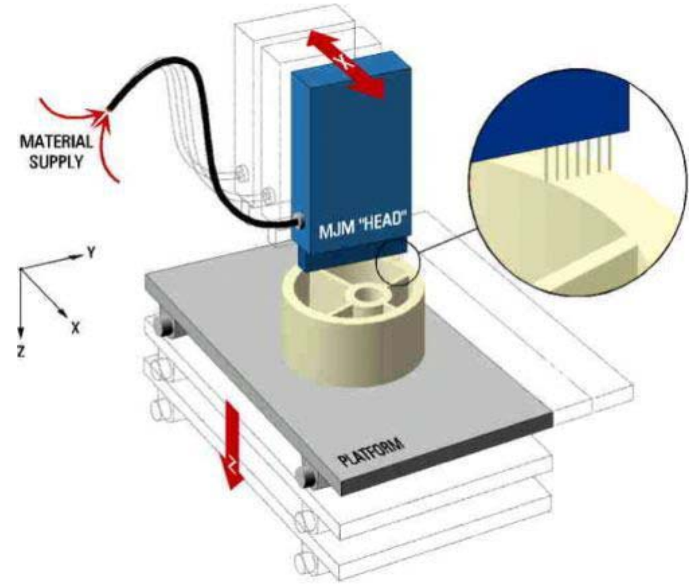
Direct Jetting

Lauren Margolin

SRL Presentation

June 7, 2005

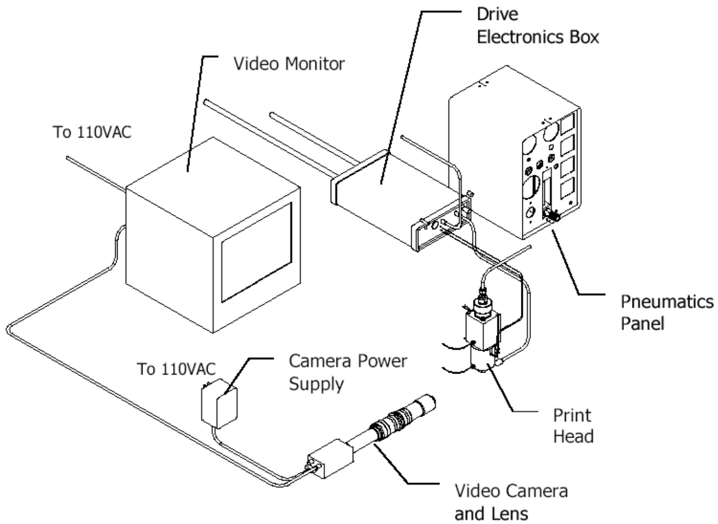
Motivation & Objectives



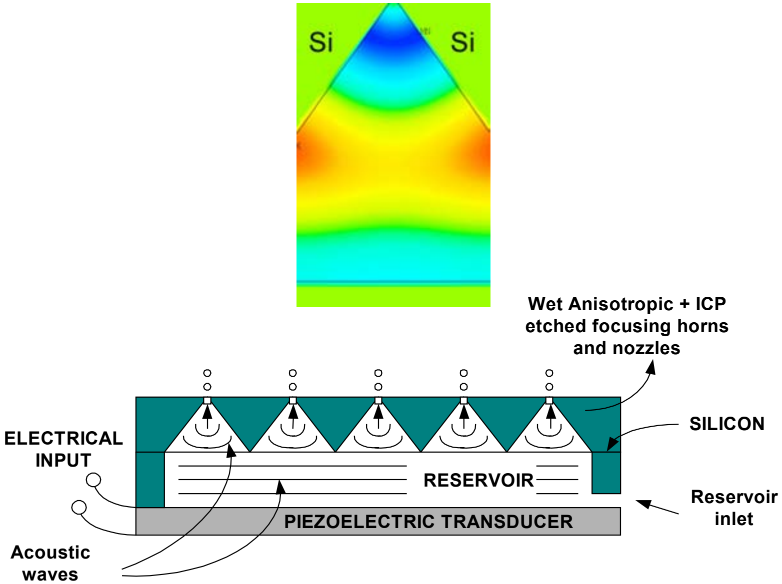
- Attempting to build 3D parts with layer-based inkjet printing
- Jetting advantages: scalable, inexpensive, graded materials
- Problem: material limitations
- Objective: how to build parts from high MW polymers with good functional properties

Approach

- Two experimental testbeds at GT



MicroFab

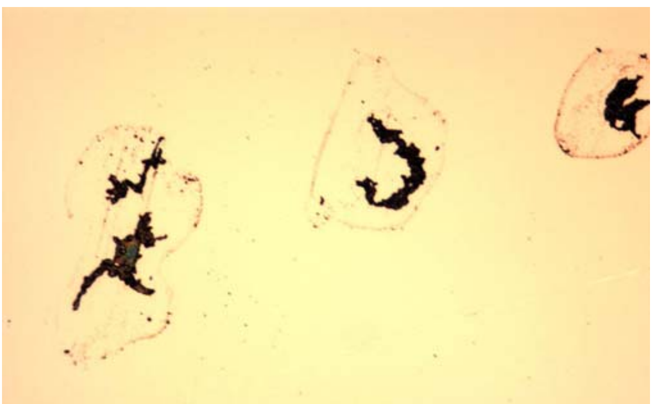


Acoustic

- Modes of liquid→solid conversion:
  solution, hot melt, post-deposition reaction (e.g. photopolymerization)

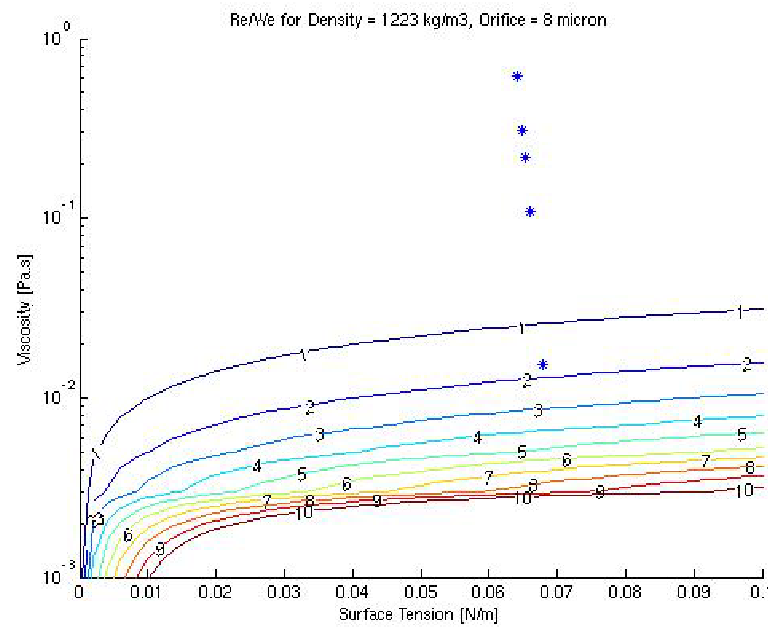
Key Results

MicroFab



TPU solution ~2%

Acoustic



Glycerine/water

Future Directions

- Identify representative materials
- Test materials on MicroFab system
- Determine operating windows for acoustic system

- Questions?

Selection for Rapid Manufacturing under Epistemic Uncertainty

Jamal Wilson

SRL Presentation

June 7, 2005

Motivation and Objectives

- Rapid Manufacturing (RM) is the use of the RP technologies to manufacture end-use products, or finished parts. Recent studies have shown that companies have a strong interest in using RP to produce customized products
- One of RM's main advantages is its ability to produce customized parts. This customization ability introduces a considerable amount of uncertainty about what the customer wants and will choose.
- This uncertainty (about what the customer will choose) equates to geometric uncertainty in the final part layout

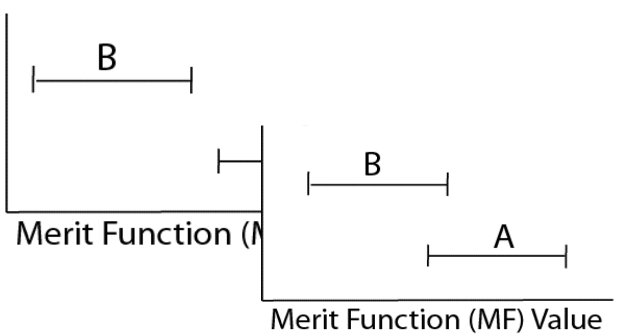
Approach

Selection DSP Word Formulation

Given: A set of feasible design alternatives
Identify: The principle attributes influencing selection, relative importance of the attributes
Rate: The alternatives with respect to each attribute
Rank: The feasible alternatives in order of preference based on the attributes and their relative importance

Epistemic Uncertainty due to Natural Variation

Uncertainty Accounting (Interval Analysis)



Decision Theory for selection under 'strict uncertainty'

Hurwicz Selection Criterion

Consider the choice between alternative A_i and jth alternatives A_j, where j=1,…,n

α = optimism-pessimism index, where $0 \le \alpha \le 1$

$$\beta_i = \alpha \cdot MF(A_i)_{\max} + (1-\alpha) \cdot MF(A_i)_{\min}$$

and

$$\beta_j = \alpha \cdot MF(A_j)_{\max} + (1-\alpha) \cdot MF(A_j)_{\min}$$

One should select alternative A_i if, and only if:

$$\beta_i > \beta_j$$

Georgia Institute of Technology

RPMI

Selection for Rapid Manufacturing under Epistemic Uncertainty

Selection for Rapid Manufacturing under Epistemic Uncertainty
Word Formulation

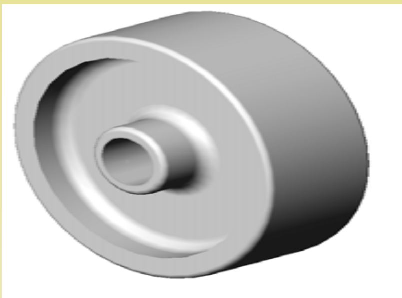
Given: A set of feasible alternatives.
Identify: The principle *attributes* influencing selection and relative importance of the attributes.
Epistemic uncertainty associated
dimensions of the part.
The decision maker's risk prefere
Assess: Geometric Characteristics that aff
Rate: The alternatives with respect to e
Rank: The feasible alternatives *using the*
of preference based on the att

Steps of Selection for Rapid Manufacturing (RM) under Epistemic Uncertainty

1. **Characterize the uncertainty involved**
   a. **Qualitatively define the Range of Customization**
   b. **Quantitatively define the uncertainty involved**
2. Describe alternatives and provide acronyms
3. Describe each relevant attribute, specify its relative importance, and provide acronyms
4. Specify levels and/or intervals for each attribute for each alternative
5. Normalize the attribute ratings
6. Rank and select the alternatives in order of preference
   a. Evaluate the merit functions
   b. **Determine decision maker's risk preferences**
   c. **Evaluate selection values and rank alternatives using Hurwicz Criterion**
7. Post Solution Analysis and Verification of results

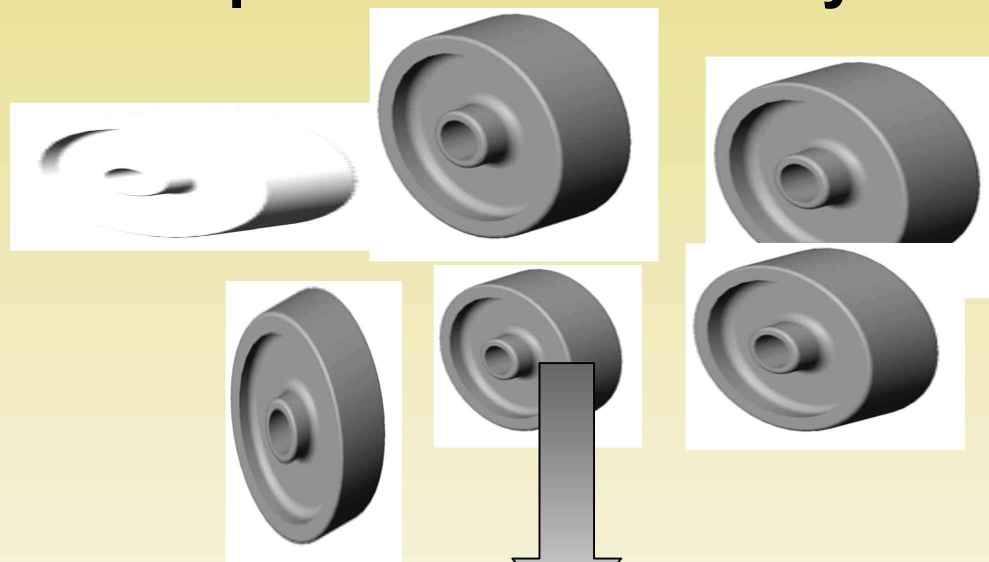
Results

Selection DSP



	MF	RANK
DMD	0.720	3
DMLS	0.254	6
EBM	0.767	1
LENS	0.694	4
SLM	0.762	2
SLS	0.536	5

Selection for RM under Epistemic Uncertainty



	HC	RANK
DMD	0.72	3
DMLS	0.2537	6
EBM	0.7435	2
LENS	0.6892	4
SLM	0.7526	1
SLS	0.5275	5

Direct Methanol Fuel Cells

Angela Tse

SRL Presentation

June 7, 2005

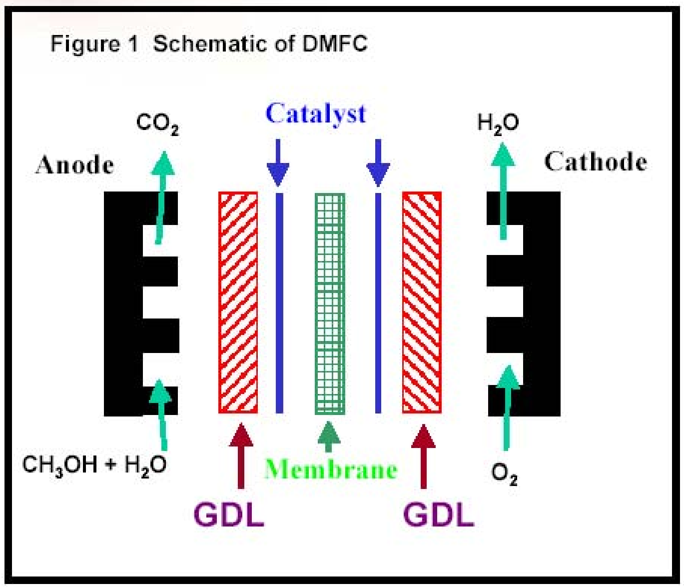
DMFC Working Principle & Applications

Direct Methanol Micro Fuel Cells

CH_3OH + "Air"

DIRECT CONVERSION

Electricity
+
Environmentally Benign Products



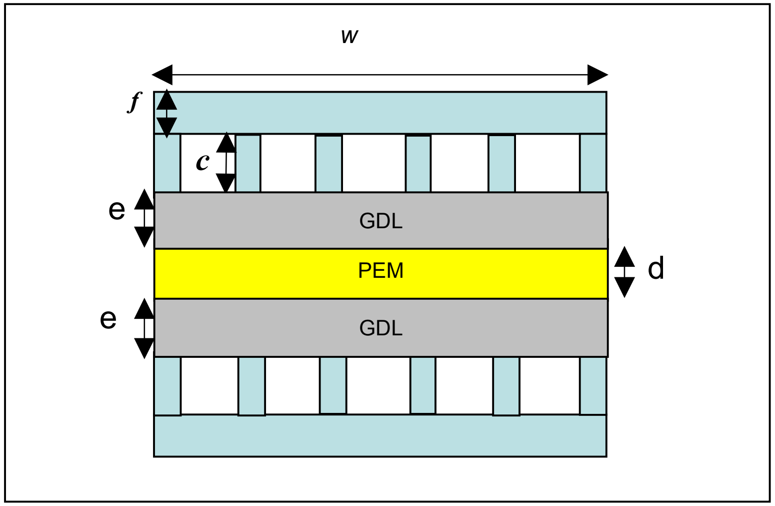
Anode: $CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$
Cathode: $6H^+ + 3/2\ O_2 \rightarrow 3H_2O$

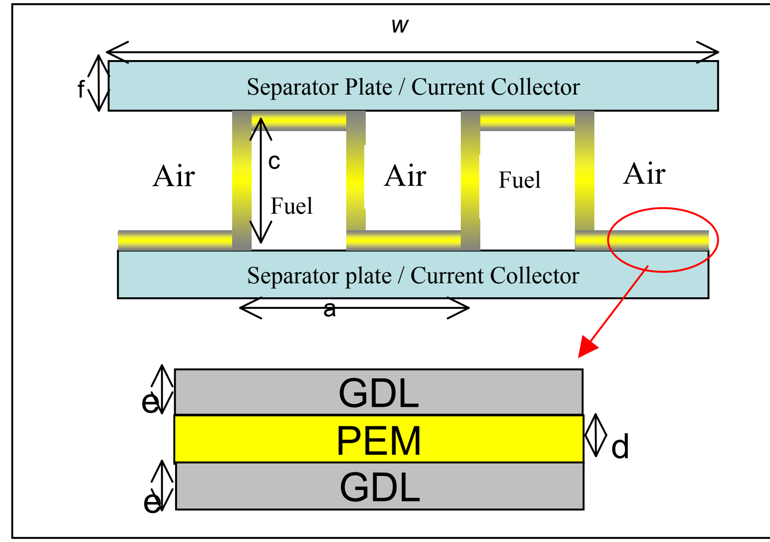
Portable Applications

Major Research Tasks

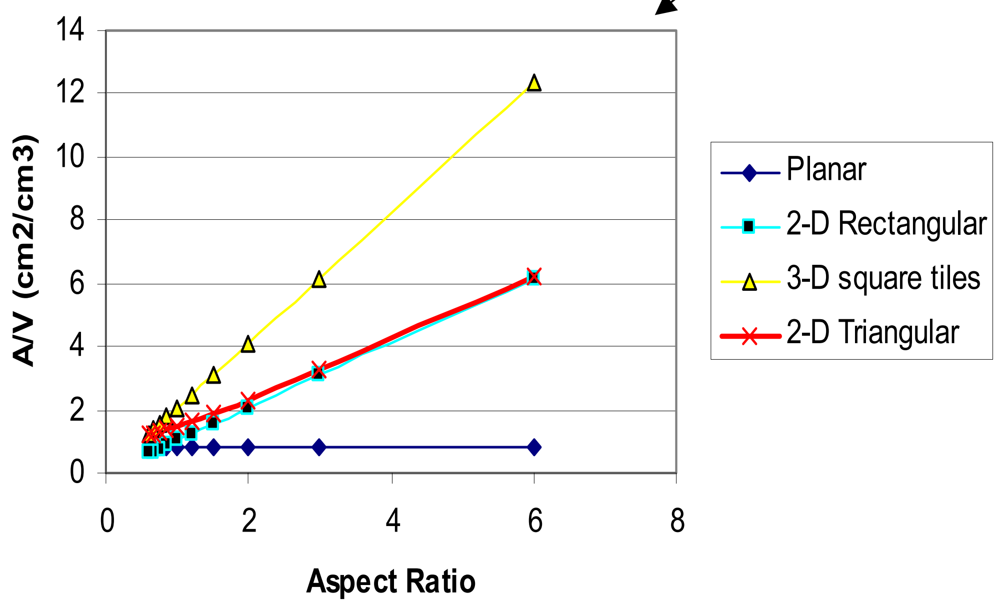
- Project Goal: Patterning Membrane-electrode assemblies (MEAs) with corrugated geometries for volumetric power density enhancement
- Optimize MEA fabrication techniques
- FEM analysis on shaping process
- 3D MEA fabrication and testing
- Stacking configuration for high packing density

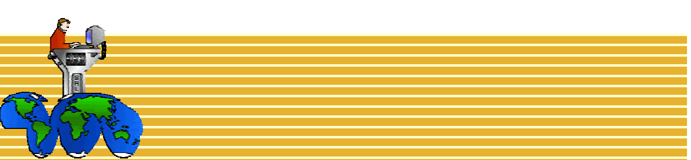
Surface Geometric Analysis





$$\frac{A}{V} = \frac{\text{Active area}}{\text{Cell volume}}$$

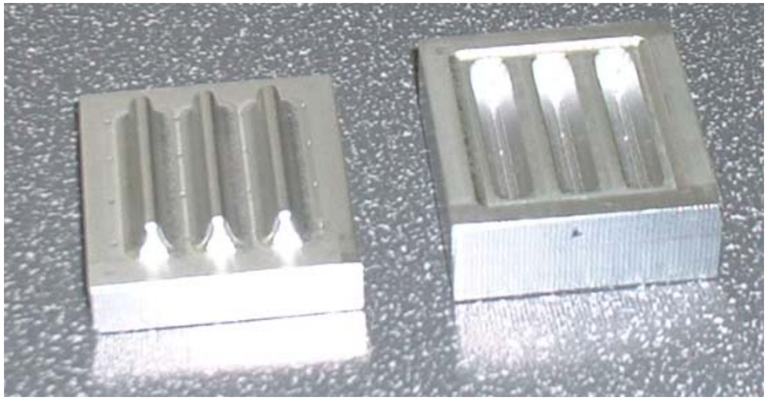




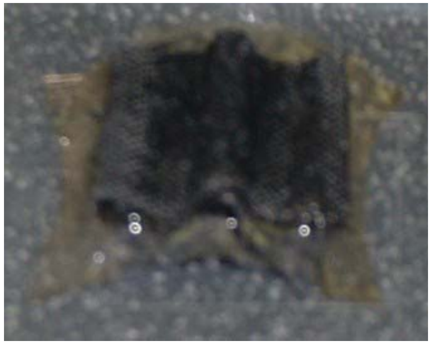
RPMI

Corrugated MEA Prototypes

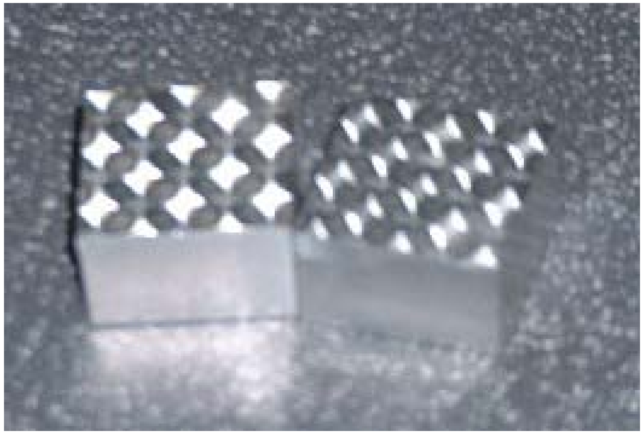
2D – Ribs Design



2D MEA with carbon cloth



3D – Dome-shape Design



3D MEA with carbon cloth